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CORPS OF ENGINEERS DISSOLVED GAS MONITORING

COLUMBIA RIVER BASIN

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Including Material Provided by:

Portland District-US Geological Survey
Engineering Research and Development Center
Walla Walla District

Water Quality Team
Reservoir Control Center, Water Management Division

EXECUTIVE SUMMARY

This Annual Dissolved Gas Monitoring Program Report for 2000 was prepared with a new format based on internal Corps review comments and on requests from the National Marine Fisheries Service Regional Forum Water Quality Team. The report provides Program descriptions in Sections 1 through 5. Included are sections on Clean Water Act and Endangered Species Act, monitoring station descriptions, a reference to the detailed 2000 Plan of Action prepared for the Technical Management Team, a summary of 2000 runoff conditions, and a summary of spill conditions. The report summarizes Program results in Sections 6 and 7. They include a review of water quality exceedances and a summary discussion of 2000 fish passage. Detailed reviews of the Program are found in Sections 8 through 12; they include detailed review of the total dissolved gas and water temperature monitoring results, a discussion of data analysis, station analysis, operational considerations, and lessons learned.

The core of the report describing the 2000 results are in Sections 6 and 7. Operation of the Corps lower four Snake River dams and the Corps lower Columbia River dams for Clean Water Act compliance was good.

Water year 2000 was 96 per cent of average, therefore, it was considered near normal.

Total Dissolved Gas (TDG) standard exceedances ranged from 1 day at John Day forebay to 58 days at Camas/Washougal during the 190-day spring/summer monitoring season at Bonneville Dam and the 168-day spring/summer monitoring season at the remainder of the locations. ~~A Poisson Analysis was performed for each fixed monitoring site providing a base measure from which future improvements in operations to reduce the number of exceedances can be measured.~~

Water temperature standard exceedances ranged between 13 and 51 days at the monitoring sites on the Columbia River, between 0 and 63 days at the Snake River sites, and between 1 and 3 days on the Clearwater sites. Dworshak Dam was able to provide waters that cooled the lower Snake River by as much as 2 degrees (F) during some summer periods.

Chronic problem fixed monitoring sites were identified to be the McNary Dam forebay and the Camas, Anatone and Lewiston riverine sites.

According to the 2000 Fish Passage Report prepared by the National Marine Fisheries Service and Fish Passage Center, a total of 21,391 juvenile salmon were examined between April and August 2000. Only 96 fish or 0.4 per cent showed signs of gas bubble trauma in fins, eyes, or lateral lines. Only three fish with signs were observed in the lower Columbia River sites.

2000 DISSOLVED GAS MONITORING
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Part I – Program Description

1. Clean Water Act and Endangered Species Act

1.1. Purpose

1.1.1. General

There are two purposes for Corps of Engineers monitoring total dissolved gas and water temperature at eight Columbia River Basin dams and preparing this report: to monitor project performance in relation to water quality standards, and to provide water quality data for anadromous fish passage at Columbia/Snake mainstem dams. The monitoring program is considered an integral part of Corps Reservoir Control Center water management activities.

Total Dissolved Gas (TDG) is the primary water quality parameter monitored. High saturation level TDG can cause physiological damage to fish. Water temperature is also measured because it affects TDG saturation levels and because it influences the health of fish and other aquatic organisms. Both TDG and water temperature are closely linked to project water management operations (e.g. water released over the spillways, releases through the powerhouses and other facilities, forebay and tailwater water surface elevations).

1.1.2. Corps Goals

The general policies of the Corps of Engineers are summarized in the **Corps Digest of Water Resources Policies and Authorities**, Engineering Pamphlet 1165-2-1, dated February 1996. The Corps policy is to comply with water quality standards to the extent practicable regarding nationwide operation of water resources projects. "Although water quality legislation does not require permits for discharges from reservoirs, downstream water quality standards should be met whenever possible. When releases are found to be incompatible with state standards they should be studied to establish an appropriate course of action for upgrading release quality, for the opportunity to improve water quality in support of ecosystem restoration, or for otherwise meeting their potential to best serve downstream needs. Any physical or operational modification to a project (for purposes other than water quality) shall not degrade water quality in the reservoir or project discharges." (Section 18-3.b, page 18-5)

1.1.3. Biological Opinions for 1995 and 1998

The Corps Dissolved Gas Monitoring Program before 1984 was to voluntarily monitor for water quality standard exceedance. In 1984, the program was enhanced to serve the dual purposes stated in **1.1.11 General**. Since the listing of some Snake River salmonids under the Endangered Species Act in 1991, voluntary spill for juvenile fish passage has been examined and modified over the last ten years. According to the 1992 Biological Opinion, voluntary spill for juvenile fish for 12 hours at night was conducted at Lower Monumental, Ice Harbor, John Day, The Dalles and Bonneville dam in an attempt to achieve 70% fish passage efficiency (FPE) for spring outmigrants and 50% FPE for summer outmigrants. FPE is an estimated percentage of fish that pass the dam either over the spillway or through a bypass facility. In the NMFS 1995 BiOp, the timing, location and volume of voluntary spill was modified. 24-hour spill was initiated at Ice Harbor, The Dalles, and Bonneville dams; spill at collector projects during the spring migration was initiated; FPE was increased to 80% for all migrants. NMFS concluded that the benefits to project survival associated with fish passage spill up to 120% TDG was an acceptable risk.

The Corps addressed TDG and water temperature during the ESA consultation in 1994. In a letter from the Corps to National

Marine Fisheries Service, dated November 9, 1994, the Corps stated that "Spill for fish passage at Corps projects will be provided in 1995 according to the Fish Passage Plan (FPP) criteria, including any modifications agreed upon in consultation under the Endangered Species Act (ESA)…Also, any necessary waivers of water quality standards must be obtained beforehand from appropriate state or Federal authorities..."

The 1998 Supplemental BiOp replaced the FPE goals with spill levels up to 120% TDG. The NMFS 1998 BiOp also asked the Corps to test increasing voluntary spill at John Day Dam from 12 hours to 24 hours. Therefore, in order to meet the ESA requirements of avoiding jeopardy to listed salmonids, the Corps has been asked to provide voluntary fish passage spill which exceeds state water quality standards of 110% TDG.Relevant sections of the 1995 and 1998 BiOps regarding operations that impact TDG levels and water temperature include:

TDG

RPA #2 in the 1995 BiOp identified additional voluntary spill at the lower Snake river projects to achieve 80 percent fish passage efficiency (FPE) and survival of migrating juvenile salmonids (1995 BiOp, pages 104 - 110). At certain projects, voluntary spill up to 110 per cent TDG would not achieve 80 per cent FPE. Therefore, recommending spill levels above the state water quality standard of 110 per cent. NMFS considered the risk of the elevated levels of TDG on migrating salmon and decided the risk was acceptable. In the 1998 Supplemental Biological Assessment, the action agencies proposed that voluntary spill be minimized at lower Snake River projects due to concerns of high TDG and to maximize fish transportation by barges. During consultation with NMFS this proposal was amended and the 1998 Supplemental BiOp increased the voluntary spill levels partially based on observations made after 1995. "NMFS also believes that moving past the per-project FPE goals (stated in the 1995 RPA) to further increase juvenile survival would not violate the intent of the requests to the state water quality agencies for dissolved gas waivers." (98BiOp, page c-4) NMFS recommended maximum spill up to the higher total dissolved gas levels rather than curtailing spill when 80% FPE were achieved, which the Corps agreed to implement. (98ROCASOD)

Water Temperature

Water management operations to reduce water temperature in the lower Snake River for the benefit of adult Snake River fall Chinook salmon were considered. (95 BiOpIV.A.1.g, pages 44 - 45) The BiOp concluded that although the priority for cool water releases from Dworshak Dam were for migrating juvenile fall chinook in July and August, releases to reduce water temperatures in September could be considered on an annual basis through the NMFS Regional Forum's Technical Management Team. Incidental Take Statement # 17 of the 1995 BiOp specifically recognizes the potential releases from Dworshak Dam for water temperature control.

Incidental Take Statement # 5 of the 1995 BiOp also recognizes special operating criteria to mitigate adverse warm water conditions that periodically occur at McNary Dam in the summer.

1.1.4. Operating Guidelines

The Water Quality Team of the Reservoir Control Center is responsible for monitoring the TDG and water temperature conditions in the forebays and the tailwaters of each of the eight lower Columbia River/lower Snake River dams, and selected river sites. The operational water management guidelines are to change spill levels and, subsequently, spill patterns at the dams (daily if necessary) so that the forebays are as close to, but do not exceed, 115 per cent TDG and the tailwater are as close to, but do not exceed, 120 per cent TDG.

2. Monitoring Stations

Total Dissolved Gas (TDG) and temperature are monitored throughout the Columbia River basin using fixed monitoring stations (FMSs). There are a total of 41 FMSs in the United States portion of the Columbia River basin. The US Bureau of Reclamation, Chelan and Grant County Public Utility District (PUD) maintain four stations each. Two stations are maintained by Douglas County PUD. The remaining stations are maintained by the US Army Corps of Engineers. It should be noted that the Corps dams on the Pend Oreille River (Albeni Falls Dam) and on the Kootenai River (Libby Dam) were not part of the fixed monitoring station program. Table 1.1 contains points of contact for each FMS. Appendix A contains a map of the fixed monitoring stations and a brief description of each of the Corps FMSs.

The Northwestern Division is not responsible for the monitoring programs of the non-Corps stations. The Corps makes non-Corps data available on the Technical Management Team (TMT) website in cooperation with inter-agency watershed management goals.

Table 1.1 List of TDG Monitoring System Contact Persons

Project	*Name*	*Position*	*Phone #*	*E-Mail/ Fax*
Kootenay and Pend d'Oreille projects/Keenleyside	Andrea Ryan Julia Beatty	Environmental Specialist Biologist	(604) 664-4001 (250) 354-6750	Andrea.ryan@gc.ca jbeatty@nelson.env.gov.bc.ca
International Boundary Hungry Horse, Grand Coulee	Sharon Churchill Dave Zimmer Jim Doty	Water Quality Specialist Biologist/Coordinator Engineer/Transmission	(509) 754-0254 (208) 378-5088 (208)378-5272	(509) 754-0239 schurchill@pn.usbr.gov
Chief Joseph, Libby	Marian Valentine David VanRijn Ray Strode	Hydraulic Engineer/ Coordinator Biologist Meteorological Tech	(206) 764-6927 (206) 764-6926 (206) 764-3529	(206)764-6678 marian.valentine@usace.army.mil (206)764-6678 david.p.vanrijn@usace.army.mil (206)764-6678 i.ray.strode@usace.army.mil
Wells (Douglas County PUD)	Rick Klinge Dan Gerber Scott Wilsey	Biologist/Coordinator Technician Program Analyst	(509) 884-2244 (509) 884-7191 x352 (509) 884-7191 x219	(509) 884-0553 rklinge@dcpud.org
Rocky Reach, Rock Island (Chelan County PUD)	Robert MacDonald	Biologist/Coordinator	(509) 663-8121	(509) 664-2898 robertmc@chelanpud.org
Wanapum, Priest Rapids (Grant County PUD)	Tom Dresser	Biologist/Coordinator	(509) 754-5088 x2312	
Dworshak, Lower Granite Little Goose, Lower Monumental Ice Harbor, McNary	Dave Reese Gary Slack Tom Miller Russ Heaton	Hydraulic Engineer/ Coordinator Technician Limnologist Technician	(509) 527-7283 (509)527-7636 (509) 527-7279 (509) 527-7282	David.l.reese@nww01.usace.army.mil Gary.m.slack@nww01.usace.army.mil Thomas.d.miller@nww01.usace.army.mil Russ.d.heaton@nww01.usace.army.mil
John Day, The Dalles, Warrendale, Skamania, Camas/Washougal	Jim Britton Joe Rinella Dwight Tanner	Biologist/Coordinator USGS USGS	(503)808-4888 (503) 251-3278 (503) 251 3289	James.l.britton@nwp01.usace.army.mil Jrinella@usgs.gov
US Army Corps of Engineers Coordination	Richard Cassidy Ruth Abney	Environmental Engineer Hydrologic Technician	(503) 808-3938 (503) 808-3939	Richard.A.Cassidy@usace.army.mil Ruth.A.Abney@usace.army.mil
Willamette Valley Projects	Bob Magne	Biologist	(541) 937-2131	Robert.a.magne@usace.army.mil
Common Sensing, Inc	Brian D'Aoust	Company President	(208) 266-1541	(208) 266-1428 Comsen@dmi.net
HydroLab, Inc	Jim Flynn	Electrician	(800) 949-3766 x242	Jimflynn@hydrolab.com

3. Monitoring Plan of Action

The Corps prepares a dissolved gas Plan of Action each year. It is a supporting document of the National Marine Fisheries Service Regional Forum Technical Management Team (TMT). The 1995 Biological Opinion called for the establishment of a Technical Management Team to make recommendations to operating agencies to optimize passage conditions at dams for juvenile and adult anadromous salmonids for the Columbia/Snake hydro system. The 1995 Biological Opinion, and subsequent BiOps, called for the establishment of a Technical Management Team to optimize passage conditions at dams for juvenile and adult anadromous salmonids. A website description of the TMT can be found at:

http://www.nwd-wc.usace.army.mil/TMT/

The 2000 Plan of Action can be found listed under the Supporting Documents category of the 2000 TMT web page. The web address is:

http://www.nwd-wc.usace.army.mil/TMT/2000/documents/tdg/

It is also attached in Appendix B. The Plan summarizes the role and responsibilities of the Corps as they relate to dissolved gas monitoring, and what to measure, how, where, and when to take the measurements and how to analyze and interpret the resulting data. It also provides for periodic review and alteration or redirection of efforts when monitoring results and/or new information from other sources justifies a change. The Plan identifies channels of communications with other cooperating agencies and interested parties.

Part II – Program Operating Conditions

4. Water Year Runoff Conditions

Precipitation during water year 2000 in the upper Columbia River Basin was 100 per cent of normal (1961 - 1990) above Grand Coulee Dam, 85 per cent of normal in the Snake River upstream of Ice Harbor Dam, and 96 per cent of normal in the Columbia River above The Dalles, Oregon (Western Region Climate Center). The accumulated runoff for water year 2000 was 115,200 cubic feet per second or 102 per cent of average (1961 - 1990) above The Dalles. On the Snake River above Weiser, Idaho the accumulated runoff was 13,610 cubic feet per second or 84 per cent of average. This information was obtained from the US Geological Survey and Natural Resources Conservation Service.

5. Release Conditions

5.1 Spill

5.1.1. Special Spill Operations

There were three special spill operations in 2000, a Bonneville/Spring Creek Hatchery release operation, a Bonneville/John Day daytime spill amount test, and a John Day deflector spill test.

Only the Bonneville/John Day daytime spill amount test caused chronic TDG standard exceedances. The daytime spill amounts at John Day and Bonneville were varied from normal operating amounts from April 20 to August 29, 2000. At Bonneville, the daytime spill amount was varied between the normal daytime spill level of 75 kcfs and a test condition of spilling to the 120/115% TDG gas cap. The primary purpose of this test was to determine the effects of the higher spill amounts on adult fallback to see if the spill level could be increased without harmful effects on adult passage. At John Day, the daytime spill amount was varied between the normal 0% daytime spill and 30% spill. The primary purpose of this test was to see the effect of the increased spill on juvenile fish passage. At both projects, adult and juvenile fish passage was monitored to determine observed effects. These tests were designed using a randomized block design. Each block was six days long and consisted of 2 three-day test periods. The test consisted of spilling either 0% or 30% during daytime hours at John Day and spilling during the daytime at Bonneville to either the 75 kcfs adult fallback cap or the 120/115%TDG gas cap.

These two tests were linked. On the days that John Day was spilling 30% of flow during daytime Bonneville was spilling to the 75 kcfs adult fallback limit. Conversely, on the days that John Day was spilling 0% of the flow during the day Bonneville was spilling during the day to the 120% TDG cap.

The testing at these two projects caused parcels or blocks of water with differing levels of TDG to occur. The leading and trailing edges of the parcels, characterized by different gas levels, and the travel time affected by tidal influences made compliance with the 115 % cap at Camas a chronic problem.

This long-term test resulted in 6-12 days of exceedence of the 120% cap at Warrendale, Skamania and the tailrace of John Day. The results at Camas were 58 days over 115%, mainly because of large volume of daytime spill patterns producing higher gas per volume spill. It has been observed that gas does not dissipate at a high rate in the river reach between the Bonneville tailrace and Camas.

5.1.2. Voluntary and Involuntary

Within the Columbia River Basin there is an interest in correlating TDG standard exceedances and times of involuntary spill at the projects. Appendix C: Section 1 contains a summary of voluntary and involuntary spill at the eight mainstem Snake and Columbia River projects. The information was reproduced from the Bonneville Power Administration (BPA) website.

In compiling this information it should be noted that the definitions of voluntary and involuntary spill are not straightforward or consistent. An example of the inconsistency is that some agencies define all water spilled to the spill caps as voluntary while others indicate that if there was a lack of market load during the spill that was occurring then the amount defined as voluntary would be reduced by the amount ascribed to lack of market load which would then be considered involuntary spill.

According to the definitions provided by BPA in preparing this information, involuntary spill occurred throughout the spill season at Bonneville, The Dalles and John Day Dams. The greatest percentage of involuntary spill occurred in the spring, as would be expected, due to the spring runoff. All spill at McNary dam was defined as involuntary. A portion of the spill was defined as involuntary at Ice Harbor, Lower Monumental, Little Goose and Lower Granite.

5.2 Temperature

5.2.1 Dworshak Releases

During the mid to late summer, water releases from Dworshak Dam were adjusted and used to cool the lower Snake River. Appendix C: Section 2 contains a graph showing water temperatures at Anatone, WA, and at the Lower Granite Dam forebay. The Anatone station represents mainstem Snake River temperature before influences from Dworshak Dam releases. The Lower Granite Dam forebay temperatures represent cooler conditions resulting from Dworshak dominated cool water from the Clearwater River. July and August 2000 water temperatures at the Lower Granite Dam forebay appears to often be up to 2°F cooler because of the contribution from Dworshak Dam.

Part III – Program Results

6. Water Quality Compliance Review

6.1. Total Dissolved Gas

The National Marine Fisheries Service (NMFS) 1995 and 1998 Biological Opinion Spill program was implemented to provide passage conditions for listed anadromous salmonids. The BiOp spill program results in exceedances of the state water quality standard for TDG. During the spill season the TDG level in the project forebays and tailwaters was monitored. Adjustments were made to the upstream project spill levels to maintain the average of the 12 highest values in 24 hours in project forebays at less than 115% TDG and the average of the 12 highest values in 24 hours in project tailwaters at less than 120%. The releases from Dworshak were monitored to maintain instantaneous gas levels at less than 110%, the Idaho state standard for TDG.

Appendix D: Section 1 contains a listing of the maximum and minimum TDG values measured at each FMS for each month of the spill season as well as the number of hours and days the TDG standards were exceeded each month.

Most exceedance occurrences were in April and May, during times of involuntary spill, with the exception of the Camas/Washougal gage. The Camas/Washougal TDG levels were difficult to maintain below the state standards due to water travel times from Bonneville Dam and the spill test occurring at Bonneville which oscillated between spilling to the gas cap or was limited to 75 kcfs in three day random blocks.

6.2. Temperature

Generally, the state water quality standard for Washington and Oregon for temperature is 68°F with more specific criteria about how much the temperature can increase due to human actions when the river temperature exceeds 68°F.

The NMFS 1995 and 1998 BiOps call for cold-water releases from Dworshak reservoir. These releases are to reduce and/or maintain a cooler water temperature in the Snake River in the July and August timeframe when ambient conditions would typically cause the temperature to rise above 68°F.

Appendix D: Section 2 contains a summary of the first and last hour the temperature at each station was equal to or greater than 68°F during the spill season, and the first and last day the 24-hour average temperature was equal to or greater than 68°F during the spill season. The table also contains the number of days where at least one hourly reading was equal to or greater than 68°F and the number of days the 24-hour average was equal to or greater than 68°F.

The 24-hour average temperature exceeded 68°F for between 13 and 51 days at the stations on the Columbia River. The 24-hour average temperature exceeded 68°F for between 0 and 63 days on the Snake River. The 24-hour average temperature exceeded 68°F between 1 and 3 days on the Clearwater River.

6.3. Chronic Exceedance Problems

There were four locations that were difficult to avoid exceedances, leading to chronic exceedance problems for 2000, described below: one was a project location (McNary forebay) and three were river locations (Camas on the Columbia River, Anatone on the Snake River, and Lewiston on the North Fork Clearwater River).

6.3.1. McNary

The McNary forebay is at the confluence of the Snake and Columbia Rivers and receives waters that have not been fully mixed. Consequently, the water coming from the mainstem Columbia on the Washington side of the river often contains different TDG levels and water temperatures from the waters entering from the Snake River on the Oregon side. The only control that the Corps has in changing forebay conditions at McNary are by operating Ice Harbor Dam releases on the Snake River. For example, it was difficult making decisions on how much to reduce spill at Ice Harbor Dam on the lower Snake River when TDG levels coming down the main stem Columbia River were high or above the 115 percent forebay limit. Sometimes, the TDG level in the Ice Harbor tailwater needed to be significantly reduced below the 120 per cent goal to help reduce the McNary forebay levels which were above 115 per cent. This resulted in spill levels at Ice Harbor that were less than the 120 percent called for in the Biological Opinion.

6.3.2. Camas

The Camas fixed monitoring site represents a theoretical forebay site in the lowest reach of the Columbia River, a site that is influenced by tidal interaction. Tidal interaction probably influenced the water travel time of parcels of water spilled over Bonneville Dam. Typically the travel time was 12 to 15 hours. This site was the most difficult fixed monitoring site to operate near to, without exceeding 115 per cent total dissolved gas levels. See Appendix E for a graph depicting exceedances.

This site was also significantly affected by environmental conditions such as changes in barometric pressures and changes in daily solar radiation and resulting water temperatures. Other important factors influencing problematic total dissolved gas fluctuations were the randomly determined three-day daytime spill treatments performed for fisheries experimental evaluations. The Portland District will be evaluating the representativeness of the Camas FMS in 2001.

6.3.3. Anatone

The Anatone fixed monitoring site is a riverine site representing lower Snake River conditions that enter the Lower Granite Dam pool and forebay. The site was subject to low water conditions late in the summer monitoring season. Consequently, the compensation depth at which gas bubbles could form on the membrane of the monitoring probe was exceeded. There was some natural correction to this situation because the flowing water of the river tended to sweep forming gas bubbles off the membrane so that the measurement still represented the gas value of one atmosphere near the surface. See Appendix E for the TDG levels measured at this site.

6.3.4. Lewiston

The Lewiston fixed monitoring site was a Clearwater River monitoring site that also experienced the same type of compensation depth problem as at Anatone due to the level of the river. The probe at this site was actually above the surface of the water late in the summer. See Appendix E for the TDG levels measured at this site.

6.3.5. Compensation depth

There were 3 tailwater fixed monitoring sites that could be characterized as being shallow for portions of the spring/summer monitoring season. These were Anatone, Lewiston and Warrendale. Compensation depth problems began in mid-July at the Lewiston gage and in late August 2000, at the Warrendale gage and remained an issue through September 15, 2000. Gage depth will be measured at each site in 2001. This information, as well as the calculated compensation depth, will be posted with the hourly data on the TMT website.

7. Fish Passage Summary

An annual report on water year 2000 fish passage for the Columbia River prepared by NMFS and the Fish Passage Center can be found at http://www.fpc.org/fpc_docs.htm. According to the report, the monitoring of juvenile salmonids was conducted at Bonneville and McNary dams in the lower Columbia River, and at Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams on the Lower Snake river. A total of 21,391 juvenile salmon were examined for gas bubble trauma between April and August 2000. A total of 96 or 0.4 per cent showed some signs of gas bubble trauma in fins, eyes, or lateral lines. Only 3 fish with signs were observed in the lower Columbia River sites throughout the spring and summer spill season. These were the lowest observed since monitoring began in 1995.

8. TDG and Water Temperature Monitoring Results

8.1. TDG – Average of the high 12 values in 24 hours

Consistency with state water quality standards for TDG in Oregon and Washington is based on the calculation of the average of the 12 highest values in a 24-hour period. Appendix E contains charts of the calculated TDG values for each monitoring station during the spill season along with a representation of the applicable standard (forebay at 115% or tailwater at 120%).

There were 95 exceedances among all locations on the Snake River with the most problematic locations being the Lower Monumental and Ice Harbor forebays. There were also exceedances at the Columbia River mainstem monitoring stations with the Camas/Washougal gage exhibiting 58 days over state standards.

8.2. TDG – Hourly flow, spill and TDG

Supersaturated water is a result of spill operations at the projects. The charts contained in Appendix F represent the hourly flow, spill and TDG data for each monitoring station. These charts show the relationship between elevated TDG levels and spill.

The Lower Granite tailwater graph is a good representation of the relationship between spill and TDG. During June, operations at the project were varying between 0 spill and the 120% spill cap. The TDG fluctuations directly track the changes in spill.

8.3. Temperature – Hourly data

Appendix G contains graphical hourly temperature data. Temperature exceeded 68°F on the Snake River at Anatone, Lower Granite forebay, Little Goose forebay and tailwater, Lower Monumental forebay and tailwater, Ice Harbor forebay and tailwater for most of July and August.

Temperature exceeded 68°F on the Columbia River at McNary forebays (Oregon and Washington) and tailwater, John Day forebay and tailwater, The Dalles forebay and tailwater, Bonneville forebay, Skamania, Warrendale and Camas/Washougal for most of July and August.

9. Data Analysis

9.1. Data Collection

9.1.1. Environmental Factors

The Total Dissolved Gas (TDG) concentrations measured within the Columbia and Lower Snake River reaches are a function of solubility, water temperature, pressure, and gas composition, and are influenced by daily project operations of the hydropower system.

The TDG pressure in water is composed of the sum of the partial pressures of atmospheric gases dissolved in the water. The primary gases making up TDG pressure in water are nitrogen, oxygen, carbon dioxide and argon and the atmospheric composition of these gases are 78.084, 20.946, 0.934 and 0.032 per cent respectively. In most freshwater systems the partial pressure of carbon dioxide and argon are considered negligible as they contribute less than 1% to the total TDG pressure composition.

Each gas exerts a pressure, its partial pressure, in a volume of a mixture and the solubility of TDG is directly related to these partial pressures exerted in the water column. Each gas exerts the same pressure that it would exert if it alone occupied a volume of water at a given temperature. Dalton's Law and Henry's Law help describe the behavior of gases. According to Dalton's Law, the total pressure exerted by the mixture of gases is equal to the sum of the partial pressures of the constituent gases. Henry’s Law is an equation of state that relates the solubility (mass/volume typically mg/l) of a given gas to the partial pressure (mm Hg) at equilibrium. The constant of proportionality between the partial pressure and solubility is called Henry’s constant or the Bunsen coefficient. The constant of proportionality is a function of barometric pressure, temperature, and salinity. The mass of dissolved gases in water can be determined from estimates of the TDG pressure, water temperature, and barometric pressure (assuming atmospheric composition of gases in solution and the air is saturated with water vapor).

Solubility is the degree to which an individual gas dissolves into a liquid and varies directly with absolute pressure at sample depth. The total pressure is a measurement that combines the effects of barometric pressure and the hydrostatic pressure. When the barometric pressure changes, there is usually a resultant change in the total dissolved gas pressure, and consequently, in solubility. A rise in barometric pressure will result in a reduction in the percent saturation although the total mass and pressure of dissolved gas remains unchanged. For example, average barometric pressures are lower at higher elevations. Even if total mass and pressure of the dissolved gases remained unchanged, a100-ft elevation drop would translate into an increase in barometric pressure of about 2.7 mm Hg resulting in a slightly higher percent saturation at the higher elevation.

In late March 2000, there were barometric pressure changes in the Snake River Basin that affected the total dissolved gas readings at the monitor. It was most noticeable in the Lower Granite Dam forebay March 20 through 22, 2000. During March 20 and 21, the barometric pressure was between 752 and 746 mm Hg. On March 22, the barometric pressure dropped to the 739 - 740 mm Hg range. Because of the decreased solubility of dissolved gases with the change in barometric pressure, the total gas saturation level increased to supersaturated conditions even though little or no spill was occurring in the Snake River system. The occurrence is less noticeable but still identifiable at Little Goose and Lower Monumental dams and least noticeable at Ice Harbor Dam.

Under most conditions, water temperature increases closer to the surface of the water column. Temperature gradients can cause pressure increases of several mm of Hg. Warming of water without corresponding equilibrium with the atmosphere can cause significant supersaturation. A 1-degree Celsius change in water temperature is equivalent to about a 12 mm Hg (2% saturation) change in the total dissolved gas pressure. As the temperature increases, solubility decreases. For example, the solubility of nitrogen at zero degrees Celsius (or 32 degrees Fahrenheit) is 55 per cent greater than at 20 degrees (Celsius, or 68 degrees Fahrenheit). The physical manifestation of this decreased solubility is readily forming gas bubbles that rapidly vent out of the water column. Barring any other environmental changes, this increase in temperature translates into higher TDG pressure readings by the monitor.

Daily water temperature variations caused by solar radiation during clear days, following extended periods of cloudy conditions at a monitoring station measuring at 15-foot depth, cause increases in TDG pressure in late afternoon. This is because the gases within the surface waters have not had sufficient time to reach equilibrium with the atmosphere. Typically, the total dissolved gas pressure in the mass of water for a specific river reach does not change, however, it takes several hours for the monitor to equilibrate from the barometric changes and the water temperature changes. Since the solar radiation lasts for only a portion of the day, the monitor can be recording unstable conditions that appear to be supersaturated for several hours. The monitors actually show only a segment of the water column and may appear exaggerated. See the daily total dissolved gas cap changes at the Corps dams made on the lower Snake River during the first two weeks of June 2000 for an example of this phenomena. The daily decision rationale for adjusting spill levels including consideration of fluctuating daily air temperatures are shown in Appendix H.

Other environmental factors that affect total dissolved gas pressure include photosynthesis, respiration, wind mixing effects, and salinity levels. Photosynthesis occurs as plankton metabolizes, producing oxygen whilst respiration by plankton consumes oxygen. A 1-mg/l change in the dissolved oxygen concentration level can result in a 14 to 17 mm Hg total dissolved gas change between 10 and 20 degrees Celsius (50 to 68 degrees Fahrenheit), or a 2% change in the gas saturation level. Salinity reduces TDG pressure and increases the percent of partial pressure. Wind mixing occurs extensively in the John Day pool, causing fluctuations in gas pressures.

9.2. Operational Factors

The Dissolved Gas Abatement Team conducted a five-year joint study to better understand the TDG production systems occurring at the eight Lower Columbia River projects. The study has provided a greater understanding of the processes and much of this work will be available in the Phase II Dissolved Gas Abatement Technical Report. In general, TDG exchange processes can be divided into two broad categories: near field and in-pool.

Though these processes are complex, some patterns do emerge. Using the ERDC-generated TDG production equations, the Reservoir Control Center formulates an annual spill priority list to allot spill to projects in a manner that best manages TDG levels to the state water quality standards.

RCC assigns voluntary spill levels to each project during the spill season, however this spill level may vary in-season because of environmental, operational or hydrodynamic factors. For example, temperature may rise, resulting in higher TDG for the same spill level. Unit outages may occur, forcing more spill but at a lower total percent powerhouse discharge and the voluntary spill level may need to be lowered accordingly.

9.3. Hydrodynamics/Spill

Each Corps of Engineers hydropower project produces TDG levels unique to that project. Most of the TDG is generated through spillway related activities. In general, spillway water falls over or moves through the dam spillway and the increased air-water interface causes atmospheric gases to go into solution. The water is forced deep into the plunge pools of the dams and the water can pressurize several atmospheres of hydrostatic pressure from the weight of the water, causing gas supersaturation. For example, at a depth of 15-feet the absolute saturation value is 45 % more that the saturated value at the surface (e.g. 155% at the surface is equivalent to 110% at 15 feet).

The hydrodynamics associated with the interactions of the spillway and powerhouse is unique to each project and is, as the word implies, dynamic. The hydrodynamic processes between powerhouse and spillway flows may vary throughout a given day through changes including total river flow, percent powerhouse to spillway discharge and incoming TDG levels. The processes at some projects are more complicated than others. Bonneville is particularly difficult to manage to state water quality standards for several reasons such as variable flow from two powerhouses and the unique bathymetric features of the dam spillway stilling basin.

9.4. Standards of Measurement

Various approaches may be taken in quantifying dissolved gases using the standard parameter of TDG expressed either as a percent of saturation (in relation to local atmospheric pressure) or as delta pressure (total gas pressure as mm Hg in excess of the local atmospheric pressure, ΔP). The Standard Methods for the Examination of Water and Wastewater, 20th Edition, (authored by the American Public Health Association, American Water Works Association and the Water Environment Federation) discourages reporting total dissolved gases in terms of percent saturation, concentration or volume units and prefers describing TDG in terms of pressures. However, within the Columbia River Basin hydropower management community, it has become conventional to express the total dissolved gas concentrations as per cent (%) of saturation as measured at the surface, or zero depth. The test criteria for acceptable aquatic habitat as applied to fresh waters for protection of biological communities is generally the universally accepted federal Clean Water Act standard of 110 percent saturation as compared to barometric pressure for the reach.

As mentioned, dissolved gas pressures are generally measured and reported as ΔP and TDG (percent) with respect to local barometric pressure (Colt, 1984). The actual or effective ΔP or TDG (percent) experienced by aquatic organism at depth as determined by the equilibrium solubility of a bubble at depth is the uncompensated pressure (Colt, 1984, 1983, and SM 1992). These values are calculated according to equations presented in "Computations of Dissolved Gas Concentration in Water as Functions of Temperature, Salinity, and Pressure" (Colt, 1984) and incorporate the physical effects of hydrostatic head on the gas solubility.

$$\Delta P_{uncomp} = TDGP - (BP + P_{Hydrostatic});$$
$$TDG_{uncomp} = [(BP+\Delta P)/(BP+ P_{Hydrostatic})]\,100;$$

The hydrostatic head is:

$$P_{Hydrostatic} = \rho g Z,$$

where ρ = the density of water in kg/m
g = acceleration of gravity (9.80655 m/s^2)
Z = depth in meters.

Gas bubbles form only when the TDG pressure is greater than the sum of compensating pressures (SM, 1992). These compensating pressures include the water (or hydrostatic) as well as barometric pressure. For organisms, tissue or blood pressure may add to the compensating pressures. Gas bubble disease or trauma can only result if internal ΔP_{uncomp} is greater than 0 or the TDG_{uncomp} is greater than 100 percent (see Section 2). The depth where $\Delta P_{uncomp} = 0$ is referred to as the hydrostatic compensation depth.

Below this compensation depth it is not possible for the dissolved gases to form bubbles or to come out of solution. Above this depth bubbles can form either internal to biological organisms or in the water column. Bubble formation on the silicone rubber tubing used by membrane diffusion instruments can seriously reduce the measurement accuracy (SM, 1992). The formation of bubbles on the membrane, which can be expected to occur at depths shallower than compensation depth, can induce a downward bias into the measure in relation to the hydrostatic pressure for that depth. If the probe is situated at 15 feet (or about a half a standard atmosphere), and TDG is managed to 120% or less, then no bubbles would be expected to form on the monitor membrane and hence no bias in the monitor measures. Positioning the monitor to at least 15 feet offers the additional advantage of being deep enough not to be uncovered during pool fluctuations and is generally representative of the entire water column. Sites that often do not meet the minimum depth of 15 feet include Warrendale and Skamania on the Lower Columbia River, Lewiston and Peck on the Clearwater River and Anatone on the Upper Snake River.

There are several basic methods to measure total dissolved gases including a manometric, volumetric, mass spectrometric, gas chromatographic, chemical titrimetric or the most common method, the direct pressure transducer method. The Corps uses the direct pressure transducer method for the fixed monitoring stations as described in this report. This analytical technique is efficient and is considered more precise than other methods of measurement.

9.5. Instrument Errors/Data Bias:

Measurement inaccuracies in data collection arise from many sources. They can originate from the position, location or operation of the instrument, or from the instrument itself. An error in any one measurement is considered a fixed, given value. The possible value of that error is described as an uncertainty. It is a statistical variable that can be arrived at through a process of uncertainty analysis. Typically, the measurement reported is considered to be the mean estimate. The uncertainty describes the variation of the measurement about the mean. The uncertainty of any measurement is defined as a combination of precision (random) uncertainty and bias (fixed or systematic) uncertainty. (Abernathy, Benedict, and Dowdell 1985). Precision uncertainty can be introduced into any repeated measurement by the variability of the instrument. Bias uncertainty will similarly effect each measurement resulting from a calibration or positioning error. Refer to Appendix I for discussions from each district on the instrument error for their stations.

9.6. Data Completeness

9.6.1. Data Corrections

Corrections to the data received from the FMSs were made throughout the monitoring season. These corrections were not available in the real-time reports for operational decision-making but they are reflected in the historical reports on the TMT webpage.

Corrections, in this context, mean that data values were changed if said changes were provided by the district or district representatives in the form of instrument drift or data shifts. Data was also removed from the database in the following instances:

- The barometric pressure data was reviewed and values <700 or >800 mmHg were removed.

- The TDG pressure data was reviewed and values <700 or >1100 mmHg were removed.

- The TDG pressure data was reviewed and changes between hourly values of >50 mmHG were removed.

- Temperature data was reviewed and temperatures >75°F were removed.

9.6.2. Overview of TDG Data Completeness

STATION	15 Dec 1999- 15 Mar 2000	1 Apr - 15 Sep 2000
Anatone (ANQW)	99.7%	99.6%
Bonneville (BON)	N/A	97%
Camas/Washougal (CWMW)	N/A	99%
Chief Joseph (CHJ)	N/A	99%
Downstream (CHQW)	N/A	99%
Peck (PEKI)	N/A	94%
Dworshak (DWQI)	97%	97%
Ice Harbor (IHR)	95%	99.6%
Tailwater (IDSW)	97%	99%
John Day (JDA)	N/A	99%
Tailwater (JHAW)	N/A	99%
Lewiston (LEWI)	N/A	89%
Little Goose (LGS)	N/A	99.9%
Tailwater (LGSW)	N/A	99%
Lower Granite (LWG)	99.7%	99.9%
Tailwater (LGNW)	95%	99.8%
Lower Monumental (LMN)	N/A	99.7%
Tailwater (LMNW)	N/A	98%
McNary (MCN)		
Oregon Forebay (MCQO)	99.7%	99%
Washington Forebay (MCQW)	99%	99.9%
Tailwater (MCPW)	99.7%	99%
Pasco (PAQW)	N/A	98%
Skamania (SKAW)	N/A	99.3%
The Dalles (TDA)	N/A	98%
Downstream (TDDO)	N/A	99.8%
Warrendale (WRNO)	98%	99%

9.6.3. Overview of Temperature Data Completeness

STATION	15 Dec 1999- 15 Mar 2000	1 Apr- 15 Sep 2000
Anatone (ANQW)	99.7%	99.6%
Bonneville (BON)	N/A	97%
Camas/Washougal (CWMW)	N/A	99.5%
Chief Joseph (CHJ)	N/A	88%
Downstream (CHQW)	N/A	99%
Peck (PEKI)	N/A	94%
Dworshak (DWQI)	97%	97%
Ice Harbor (IHR)	95%	99.8%
Tailwater (IDSW)	97%	98%
John Day (JDA)	N/A	99.9%
Tailwater (JHAW)	N/A	99%
Lewiston (LEWI)	N/A	90%
Little Goose (LGS)	N/A	99.9%
Tailwater (LGSW)	N/A	99%
Lower Granite (LWG)	99.7%	99.9%
Tailwater (LGNW)	95%	99.9%
Lower Monumental (LMN)	N/A	99.8%
Tailwater (LMNW)	N/A	99%
McNary (MCN)		
Oregon Forebay (MCQO)	99.7%	99%
Washington Forebay (MCQW)	99%	99.9%
Tailwater (MCPW)	99.7%	99%
Pasco (PAQW)	N/A	99%
Skamania (SKAW)	N/A	99.6%
The Dalles (TDA)	N/A	99%
Downstream (TDDO)	N/A	99.9%
Warrendale (WRNO)	N/A	99%

9.6.4. Missing Data

There are multiple reasons why data may be missing from the data set. Examples of reasons include transmission problems, site vandalism, a tear in a membrane or, as exhibited at Lewiston, the river level dropping below the level of the FMS. All efforts are made to reduce the occurrence of missing data.

10. Station Site Analysis

10.1. Dworshak

During the 2000 spill season, cold-water releases from Dworshak reservoir were utilized to maintain cooler water temperatures in the Snake River. Temperature information from resistance thermal devices (RTDs), embedded in the face of the dam at the time of construction, along with an understanding of the overshot and undershot modes of operation of the selector gates were used to determine which elevation of water to release to attain the desired temperature.

Appendix C:Section 2 contains a graph of the Anatone and Lower Granite forebay water temperature. The cooler temperatures in the Lower Granite forebay are attributed to cold water releases from Dworshak Dam.

Appendix C:Section 2 contains graphs of the RTD data compared with temperature array data collected ~0.5 miles from the face of the dam. These charts and the in-season performance on attaining requested release temperatures indicate that the RTD array provide data sufficient for this purpose.

Appendic C:Section 2 also contains schematics of the release structures at Dworshak and some of the physical restrictions associated with them.

10.2. Station Representativeness

The information in this section has been reproduced from the Dissolved Gas Abatement Study, Phase II, 60% Draft Technical Report. Refer to chapter 13 of that document for the complete discussion and data.

OVERVIEW:

The Columbia/Snake River Total Dissolved Gas Monitoring System (TDGMS) consists of a network of water quality monitors that collect data in the forebay and tailrace of each Corp's hydro project in the Columbia and Snake River Basin. The TDGMS was established to provide total dissolved gas pressure and water temperature data for use in adjusting reservoir regulation practices to comply with state mandated total dissolved gas water quality standards. These data are now being utilized by scientists in ways that were not originally considered in the establishment and design of the TDGMS. Although the fixed monitor station (FMS) sites sample water in only one location at a given river mile, the data are being used to represent conditions across the full width of the rivers. This allows the calculation of fluxes of water quality constituents. Due to these and other research needs, the representativeness of the data generated by the TDGMS has become an issue worthy of investigation. As part of the DGAS Field Data Collection effort, an array of three to five logging water quality instruments were deployed on a transect at each FMS site. Parameters logged include total dissolved gas, temperature, and dissolved oxygen. Data collected by these logging instruments were compared to that collected by the adjacent FMSs to determine whether each FMS collected data that were representative of the in-river maximum, mean, and/or near TDG (total dissolved gas) levels.

The fixed monitor TDG readings were compared to the maximum in-river reading, the nearest in-river reading, and the flow-weighted in-river average for each point in time. Representativeness was quantified in two ways, acceptable error analysis and regression analysis.

RESULTS:

The results of the above analyses from data collected during the 1996 and 1997 sample periods can be viewed in the above referenced report. Some of the more salient results follow:

- 16 of 21 FMS's report values within 23 mm Hg of maximum in-river conditions, suggesting that only these 16 adequately measure the maximum gas values present in the river. Only 10 of 21 FMS's have R^2 values greater than 0.7 suggesting that most FMS's cannot be used to model maximum in-river TDG values.
- 18 of 22 FMS's report values within 23 mm Hg of the flow-weighted average in-river conditions. 13 of 22 FMS's have R^2 values greater than 0.7 suggesting that those FMS's values can be used to model average in-river TDG values.
- For the near quad comparison within two instrument precisions, only 6 of 21 monitors fall within acceptable error i.e., 15 of 21 monitors have more than 25% of observations that are more than 6 mm Hg different from the TDG values measured immediately adjacent in the river. That is, instrument precision is less for field measurements. Other sources of errors such as sample error must be present. None-the-less, 20 of 21 FMS's report values within 23 mm Hg of the in-river near-value TDG.

- Forebay fixed monitors are generally most representative of in-river condition, presumably because water above projects is more homogenous.
- NWP and NWW districts have similar success rates, though different equipment, maintenance protocol, and reporting systems are used.

CONCLUSIONS:
Based on the monitor comparisons presented, we conclude that MCPW, LGSW, JHAW, and LGNW monitors are performing inadequately to determine maximum in-river total dissolved gas values. JHAW, LGNW, and LMNW are performing inadequately to determine mean in-river total dissolved gas values. Thus, LGNW is satisfying neither of the possible monitor functions discussed and should be targeted for further study and possible replacement. LGSW does not reflect conditions collected in the water immediately adjacent to the monitor, therefore we recommend additional study at this FMS site.

During 2000, the Camas fixed monitoring station had the most significant chronic exceedance problems. As a result, some NMFS regional forum WQT members have requested that it have a high priority for being evaluated for it's "representativeness".

11. Operation Considerations

There were basic guidelines used to make spill management decisions in 2000. The spill management factors centered around the Corps policy not to exceed state water quality standards. Table 11.1 lists the "Spill Requirements and Other Considerations" at each project for the spill season. This table was reproduced from the 2000 Water Management Plan. For the 2000 spring/summer spill season, the National Marine Fisheries Service (NMFS) obtained variances from the states of Washington and Oregon, according to the 1995 and 1998 Biological Opinion, to have the Corps exceed the total dissolved gas standards of 110 percent in the forebays and tailwaters of the Corps projects to assist migrating salmonid smolts. Up to 115 per cent total dissolved gas (TDG) was allowed in the forebays, and up to 120 per cent in the tailwater below projects was allowed. The method used to achieve desired TDG levels was by changing the daily spill caps restricting the amount of water going over the spillways. The Washington variance is in effect until 2003, however, the Oregon variance was established for only 2000. NMFS did not pursue obtaining a variance from the state of Idaho for 2000 so spill out of Dworshak was limited to maintain TDG levels at or below 110%.

There were six operational factors that affected efforts to control TDG spill levels to within appropriate levels consistent with standards and or variances: adjusting operations for environmental factors, correcting operations to compensate for levels of exceedance, changing operations to adjust for time periods of exceedances, the rates of change of corrected operations, multi-project exceedances, and timing of operational changes.

It is the reservoir control goal to spill as close to the 115 per cent and the 120 per cent criteria as possible, without exceeding those limits. The Reservoir Control Center determined consistency with this goal based on the average of the 12 highest daily TDG readings. The daily operating goal was to have no more than 6 hours of daily TDG values over the variance limits, so that the average of the 12 highest daily values stayed below the gas caps. As discussed in 9.1, the DATA COLLECTION section of the report, environmental factors affected the daily TDG readings. When operating close to the spill caps, environmental factors sometimes negatively affected the ability to operate within TDG caps and exceedances occurred. This type of occurrence was prevalent during weekends because TDG levels are monitored less frequently.

The degree of exceedance was also a factor that affected the calculation of the12 highest daily values. If exceedances were over 1 percent of the variance, larger corrections to spill were necessary to return the location within compliance as soon as possible.

Sometimes, these abrupt corrective actions caused fluctuations throughout long river reaches. Consequently, the TDG level would be reduced more quickly but the TDG level would also drop significantly below the 115 per cent or the 120 per cent cap for several hours. This type of regulation would cause pulsating levels of TDG throughout the system.

Another spill management factor was that once exceedance occurred, the exceedances often continued for greater that 12 hours during the next day because a large mass of water had exceeded the criteria and the water travel time to the next measuring point was greater than 12 hours away. This type of occurrence was especially observed during weekends because the TDG levels are evaluated less frequently. Abrupt TDG changes resulted in lower levels quicker, but it also would cause pulsating levels of TDG throughout the system.

Multi-project exceedances occurred when project forebays exceeded 115 per cent while upstream project tailwaters were significantly below the 120 percent level. This type of exceedance occurred at the tail end of large pulses of > 115 % water masses passing through the river system.

The time that operational changes were initiated could greatly affect TDG compliance. The travel time between forebays and tailwaters greatly affected at what time operational changes should be made.

Table 11.1 Summary of Spill Requirements and Other Considerations
(1998 Supplemental BiOp and Memo issued by NMFS April 13, 2000 based on regional coordination)

Project	Flow trigger	Spill Duration	Recommended Min/Max Powerhouse Capacity (1)	Spill Cap for 120% TDG (2) at the start of the spring season	Other Considerations (per 1998 Supplemental BiOp Appendix C) to prevent eddy formation, improve fish passage, etc.
	Kcfs	**Hours**	**Kcfs**	**kcfs**	**% of flow or kcfs**
LWG	85	12 (4)	11.5/123	45	
LGS	85	12 (4)	11.5/123	60	35% max(3), page C-11
LMN	85	24(7)	11.5/123	40	50% max (3) page C-11
IHR		24	7.5/94	75	
MCN		12 (4)	50/175	120-160	
JDA		12(5)	50/	180	60% max (for flows up to 250-300) or TDG cap (whichever is less); 25% min (due to eddy)
TDA (6)		24	50/	230 (5)	(6)40% max 30% min (test).
BON		24	30 min. (BPA); see page C-14. 60 min. (FPP)	120	50 kcfs min. spill (tailrace hydraulics); 75 kcfs max. daylight hours (adult fallback)

1. Max. value is for powerhouse with units operating within 1% peak efficiency
2. Starting value subject to in-season adjustments based on real-time information
3. Levels provided in the 1998 BiOp to prevent eddy formation and maintain good adult passage conditions. May be adjusted in-season by TMT
4. Normally between 1800-0600 hours
5. From April 20th to May 14 1800 – 0600 from May 15 to July 31 1900 to 0600 and from August 1 to August 31 1800-0600 at John Day.
6. The spill percentage at The Dalles was changed to 40% in memo issued by NMFS April 13, 2000 based on regional coordination.
7. The spill time at Lower Monumental was changed from 12 hours to 24 hours in memo issued by NMFS April 13, 2000 based on regional coordination.

Notes:

Bonneville –Will test the fish passage effect of spilling to the gas cap 24 hours a day. There will a randomized block test consisting of a block of 3 days of spilling during the daylight hours to the gas cap followed by a block of limiting daytime spill to the 75 kcfs adult fallback cap, April 20th to August 30th.

John Day - Will test spilling two levels during the daytime period. A randomized block design consisting of periods of 0% spill and 30% spill during daytime has been suggested. The daytime spill amount will be linked to the spill at Bonneville. John Day would spill during the day when Bonneville was spilling to the daytime 75 kcfs cap and not spill when Bonneville was spilling to the gas cap during the day.

12. Lessons Learned

A major operational consideration for regulating to a spill cap is how to forecast the 12 highest daily readings for the next day or the next few days. There were no analytical tools available to assist in decision-making. Six factors for making spill management decisions were identified during 2000, however, they only provide secondary assistance in providing forecasting guidance. They are discussed in 11.0, Operation Considerations. Environmental factors were generally the root cause of exceedances. Secondarily, regulator decisions to adjust for environmental factors were sometimes a cause of continued exceedances. Experience and observation were the best sources of guidance in 2000.